Numerical Simulation of Steady State Heat Distribution in Polymer Concrete Heating with Aggregate Silica Sand and Shellfish

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Abstract: Environmentally friendly polymer concrete by utilizing waste has been widely developed, one of which is shellfish waste as filler and silica sand as aggregate. This study was to determine the numerical simulation of heat distribution during the heating of polymer concrete with steady state with finite difference method of concrete model polymer and to know thermal conduction characteristics micro . Variation in composition made of silica sand , seashells (1: 1) or (50 gr: 50gr. Variations in the composition of epoxy resin 25% of the total weight of sand and shells . The results of this simulation show that the maximum temperature of 80 ^{0} C is the maximum limit temperature in row one (1) column 2 to 7, row 7 column 2 to 7, and column 7. While the temperature value of each node is 55 .0987 ^{0} C is on elements (nodes) of five (5) and twenty-five (25). While most small temperature values are at the nodes of eleven (11) with a value of 3.8333 ^{0} C. heating time is needed for 360 seconds. From the graph shows that the largest increase in the amount of temperature at 1800 seconds, while the time that shows steady state at 2160 seconds with a fixed value at 80^{0}C

1 INTRODUCTION

Computational physics is one of the most important groups of sciences because it can examine the form of modeling of complex and complex equations solved by a numerical approach (Lukman Hakim, 2014).

The finite element method is one of the numerical methods used to solve equations Partial differential in engineering science and mathematics problems such as heat transfer, namely physical dividing complex problems into elements to make it easier to get solutions. Solution of each the element is then combined so that it becomes a problem for the whole problem (Vimala Rachmawati.,2015).

the research that will be discussed is heat transfer by solving equations Numerical is the research that describes the heat transfer elements that are presented to capture thermal reactions in polymer concrete which are numerically solved by the finite element method. The construct equation is criticized into a series of two-dimensional layers that are related to finite difference calculations and use the function of the form of quadrilateral elements (Vimala Rachmawati.,2015).

Heating a material is the process of transferring heat from a heat source in the form of a zinc plate which is useful to find out how fast the heat is moving and how much heat is occurring in each second. The heat transfer process is the science of predicting energy transfer that occurs due to temperature differences between objects or materials. Steady conduction heat transfer (steady state) is a conduction process where the heat value (heat) is equal to time (Halaudin, 2006).

Concrete is a construction material based on cement adhesives and aggregates in the form of sand and gravel (Calvelri, L, Miraglia, N, Papia, M. 2003).

One of the most influential material for polymer building materials concrete the aggregate of silica sand and seashell which is expected after testing this thermal conductivity is having high heat conductivity, high strength, resistance to corrosion and chemicals (Shinta Marito, 2009).

Heat transfer in polymer concrete is conduction, from high-temperature objects to low-temperature objects that have conductivity properties. the thermal productivity of a material is the size the ability of materials to conduct heat (thermal).

Mathematically, the equation of heat distribution by conduction is formulated:

$$\rho C \frac{\partial T}{\partial t} - \nabla.(k \nabla T) = q, \qquad (1)$$

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Where $\rho, C,$ and k density, heat type, and thermal conductivity of the material, respectively, are the temperature T , and q is the internal nas which is produced on the material rod.

Equation (1) is solved numerically into equation (2)

$$\boldsymbol{\frac{\partial}{\partial x}k\left(\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}k\left(\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}k\left(\frac{\partial T}{\partial z}\right)+q=\rho C\frac{\partial T}{\partial t}} \quad (2)$$

In equation two (2) is used by the element method to get a discrete model consisting of a set of *piecewise continuous functions*. Each *piecewise function is* defined for a sub domain called *finite element* up to (Wendy Destyanto, 2007). This concept applies to problem two. So that equation (2) becomes equation (3)

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}=\left(\frac{\rho c}{k}\right)\frac{\partial T}{\partial t} \quad (3)$$

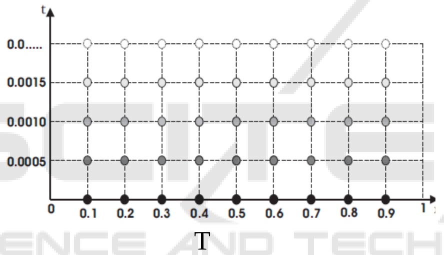

Figure1: *Mesh-points* position. Direction T shows the position of the points calculated by *forward difference*, while t direction shows an increase in time.

2 RESEARCH METHODS

2.1 Modelling

The boundary conditions used in this study are a polymer concrete sample that is modelled as an area in the conduction heat flow layer as shown in (1) below. At the upper and lower limits of the two-dimensional thermal function network elements, starting the row matrix (i) and column (j) will be given a heat source (Q) when heating the polymer concrete as much as the heat input we want. Then the thermal will propagate to each row and column matrix increment, from the row (i = 1) and column (j = 1) to the end of the row matrix and the column we want to stop. Dimensional 2 concrete model will be criticized into a field that has 36 elements and 25 nets.

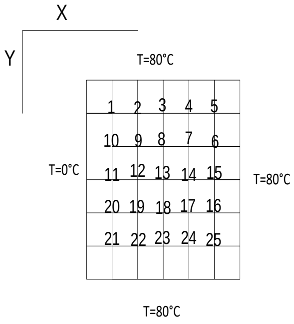

Figure 2: A model for distributing heat to elements of polymer concrete.

From equation (3) is converted to discrete or numeric form, then equation (3) will be equation (4)

$$T_{i-1,j}-2T_{i,j}+T_{i+1,j}+T_{i,j-1}-2T_{i,j}+T_{i,j+1}=\frac{\rho C}{K}\left(\frac{dT}{dt}\right) \quad (4)$$

If the width of the grid used is homogeneous and the same in the direction of x and y, then equation (4) becomes the equation (5)

$$T_{i-1,j}+T_{i+1,j}+T_{i,j-1}-4T_{i,j}+T_{i,j+1}=\frac{\rho C}{K}\left(\frac{dT}{dt}\right) \quad (5)$$

The method used in solving the heat distribution equation on the material from the Poisson equation (equation 5) in two dimensions is to use a literature study or library research approach. The steps in this study are as follows:

2.1.1 Transform the Poisson equation $\rho C y\frac{\partial T}{\partial t}-\nabla.(ky\nabla T)=qy$,along with the condition of the limit k e Cartesian coordinates

2.1.2 Discretizing the Poisson system on cartesian coordinates using a network of thermal functions and boundary conditions.

2.1.3 Substitute the input values of material conductivity (k) and mass density of polymer concrete (ρ) , heat type beto n polymer (Cv) and source heat (Q) into the Poisson equation in the form of equations of thermal function networks that have been obtained.

2.1.4 Calculate the value of the distribution of Heat $T_{i,j}$ in the network of thermal functions.

2.1.5 Perform simulations, draw graphics, and analyze errors [7].

3 RESULTS

After doing the stages of the research method, the following results are obtained:

3.1 The Value of Heat Distribution in the Polymer Concrete Model in the Form of a 2-Dimensional Matrix Measuring 7 Rows and 7 Columns (7 X 7).

From the data taken from the research of Shinta Marito, 2019, the results are used as program inputs with the help of the Matlab program , namely:

3.1.1 The mass of the polymer concrete type ρ = 2716 gram / cm3 in the addition of 80% seashell powder and 20% epoxy resin,
3.1.2 The heat coefficient of type cv = 90 kcal / gr ^{0} C
3.1.3 Heat conductivity K = 0.3 kcal / m ^{0} C
3.1.4 The initial temperature (T $_0$) = 0 ^{0} C
3.1.5 The temperature limit in row 1, row 7 in column 7 (T ^{1}) = 80 ^{0} C

Heat distribution results are obtained

3.1.6 Steady state time data (dt) = 360 seconds
3.1.7 The ratio parameter value without dimensions (rx) = 0.0442
3.1.8 Temperature distribution value (T) =

0	80.000	80.000	80.000	80.000	80.000	80.00
0	27.646	34.332	36.899	41.821	55.098	80.00
0	8.336	11.732	14.439	21.813	42.100	80.00
0	3.833	5.893	8.486	16.496	38.658	80.00
0	8.336	11.732	14.43	21.813	42.100	80.00
0	27.646	34.332	36.899	41.821	55.098	80.00
0	80.000	80.000	80.000	80.000	80.000	80.00

From the results of the study it was found that the temperature value of the largest 80 ^{0} C is the maximum limit temperature in row one (1) column 2 to 7, row 7 column 2 to 7 , and column 7. While the temperature value of each node is 55 .0987 ^{0} C is located on elements (nodes) of five (5) and twenty-five (25). While the smallest temperature value is at eleven nodes (11) with a value of 3.8333 ^{0} C. This is due to the number of elements and the number of time intervals affecting the heat distribution value of each node. The greater the number of nodes and the longer the time, the higher the level of accuracy of the heat distribution value.

3.2 Heating Results of 2-Dimensional Polymer Concrete Model

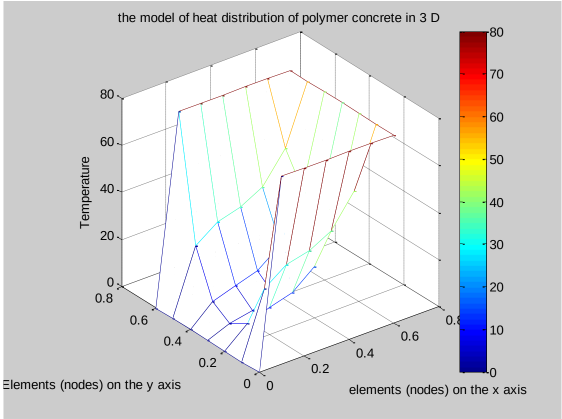

Figure 3: Visualizing heating of polymer concrete 3 (D).

3.3 The Results of Heat Distribution of 2-Dimensional Polymer Concrete

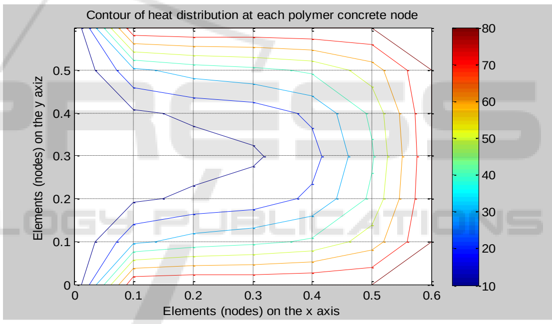

Figure 4: Visualization of heat distribution in 2 D polymer concrete models.

In the contour chart shows the temperature distribution varies. In the element area x = 0.1 the area of heat distribution is wider than in the other elements this is caused by the initial input value (To) = 0 ^{0} C and the amount of discretization is small. the more discretization elements are used then the finer the resulting contour. This can observed from the difference in contours in the seven contour lines.

3.4 Analysis of Heating Time to Increase the Temperature of Polymer Concrete

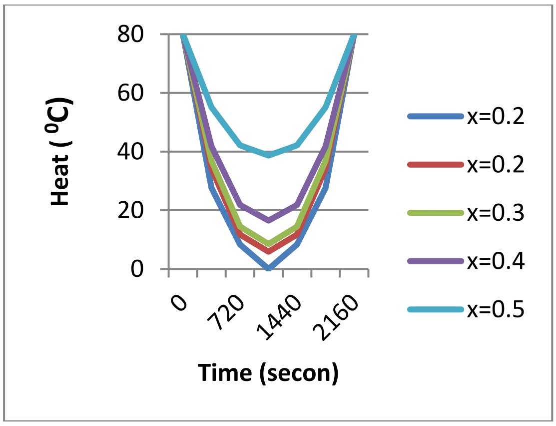

Figure 5: Heat distribution of the heating time of polymer concrete.

From the results of quantitative data that the time interval (dt) of increasing the number of two-dimensional elements x and y is 360 second / 0.1 means that each increase in the number of elements, then the heating time is required by 360 seconds. From the figure, shows that the largest increase in range temperature at 1800 seconds, while the time that shows steady state at 2160 seconds with a fixed value at 80 ^{0} C this is due to the value of the time of burning combustion. If the ring number of elements, and longer, so heat distribution and a steady state will be clearer.

4 CONCLUSIONS

From the research conducted, some conclusions can be discribed

a. The program code that is designed in the research can work well in accordance with the initial objectives of the study, namely to make numerical simulations of heat transfer on polymer concrete. Polymer concrete that is modeled in two dimensions and has 25 nets (nodes), is obtained in an interval of 360 seconds with an error rate of 0.0442 or 4.42% shows that the largest temperature 55.0987 ^{0} C is located at nodes 5 and 25. While the lowest temperature is at node eleven (11) with a value of 3.8333 ^{0} C.

b. Numerically the results of the temperature distribution of the polymer concrete layer are influenced by the number of elements used. The more elements used then the resulting temperature distribution will increase accurate even though the numerical changes are not very significant. This can be observed from changes in temperature on *the* corresponding *nodes*.

c. The number of elements used also affects the simulation. The more elements used, the more contour that is produced will be smoother or the heat transfer becomes more visible for each *node* despite the time needed for the simulation will be longer.

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